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Suppression of Dielectronic Recombination at Finite Densities

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Synopsis Density-dependent effective dielectronic recombination rate coefficients are determined in order to explore finite-density effects on the ionization balance of plasmas.

We have developed a general model for determining density-dependent effective dielectronic recombination (DR) rate coefficients in order to explore finite-density effects on the ionization balance of plasmas [1]. Our model consists of multiplying by a suppression factor those highly-accurate total zero-density DR rate coefficients which have been produced from state-of-the-art theoretical calculations and which have been benchmarked by experiment. The suppression factor is based-upon earlier detailed collision-radiative calculations which were made for a wide range of ions at various densities and temperatures [2].

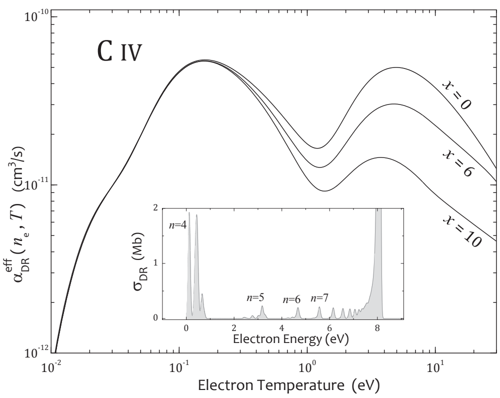

Figure 1. The inset shows the (zero-density) DR cross section convoluted with a 0.1 eV FWHM Gaussian. The spectrum is dominated by two features: the $n = 4$ DR resonance manifold below 1.0 eV and the $n \to \infty$ Rydberg resonances accumulating at the $2s \to 2p$ series limit at ≈ 8 eV. The main figure shows the effective DR rate coefficient for several (scaled) electron densities $x = \log_{10} n_e$.

A general suppression formula is then developed as a function of isoelectronic sequence, charge, density, and temperature. These density-dependent effective DR rate coefficients (see, e.g., Fig. 1) are then used in the plasma simulation code Cloudy [3] to compute ionization balance curves for both collisionally ionized and photoionized plasmas at very low ($n_e = 1$ cm^{-3}) and finite ($n_e = 10^{10}$ cm^{-3}) densities. We find that the denser case is significantly more ionized due to suppression of DR (see Fig. 2), warranting further studies of density effects on DR by detailed collisional-radiative calculations which utilize state-of-the-art partial DR rate coefficients. This is expected to impact the predictions of the ionization balance in denser cosmic gases such as those found in nova and supernova shells, accretion disks, and the broad emission line regions in active galactic nuclei.

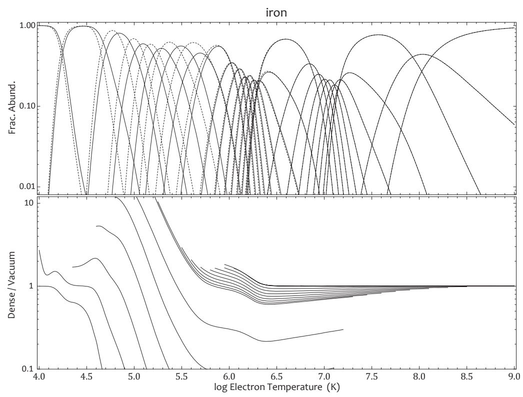

Figure 2. Upper panel: collisional ionization fractional abundance vs. electron temperature for all ionization stages of Fe. The solid curves correspond to a density of $n_e = 1$ cm^{-3} and the dashed curves correspond to a density of $n_e = 10^{10}$ cm^{-3}. From left to right, the curves range from neutral Fe to fully-ionized Fe^{26+}. Lower panel: ratio of the calculated fractional abundances for the two densities.

References

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